THE RECREATIONAL WATER QUALITY

OF

VERMILION LAKE

SUDBURY DISTRICT

Ontario
Ministry
of the
Environment

THE RECREATIONAL WATER QUALITY

OF

VERMILION LAKE

SUDBURY DISTRICT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The recreational water quality survey of Vermilion Lake was a co-operative venture between the Technical Support Section of the Northeastern Region and the Microbiology Section of the Laboratory Services Branch.

The authors, G. Myslik, G. S. Hendry, S. Janhurst and P. Bolton wish to acknowledge the contributions of the following:

H. W. Hunter and P. Juhas, for their work in the field and the preparation of maps and figures.

R. Goard for phosphorus budget calculations and figure preparation.

D. Johnston and D. Zetts for bacteriological laboratory assistance.

S. Legault for typing the manuscript.

INTRODUCTION

The questions of the Vermilion Lake Cottagers Association regarding a variety of water quality concerns including nutrient enrichment, bacteriological quality, and the lack of water quality data for the lake prompted a survey during the summer of 1976.

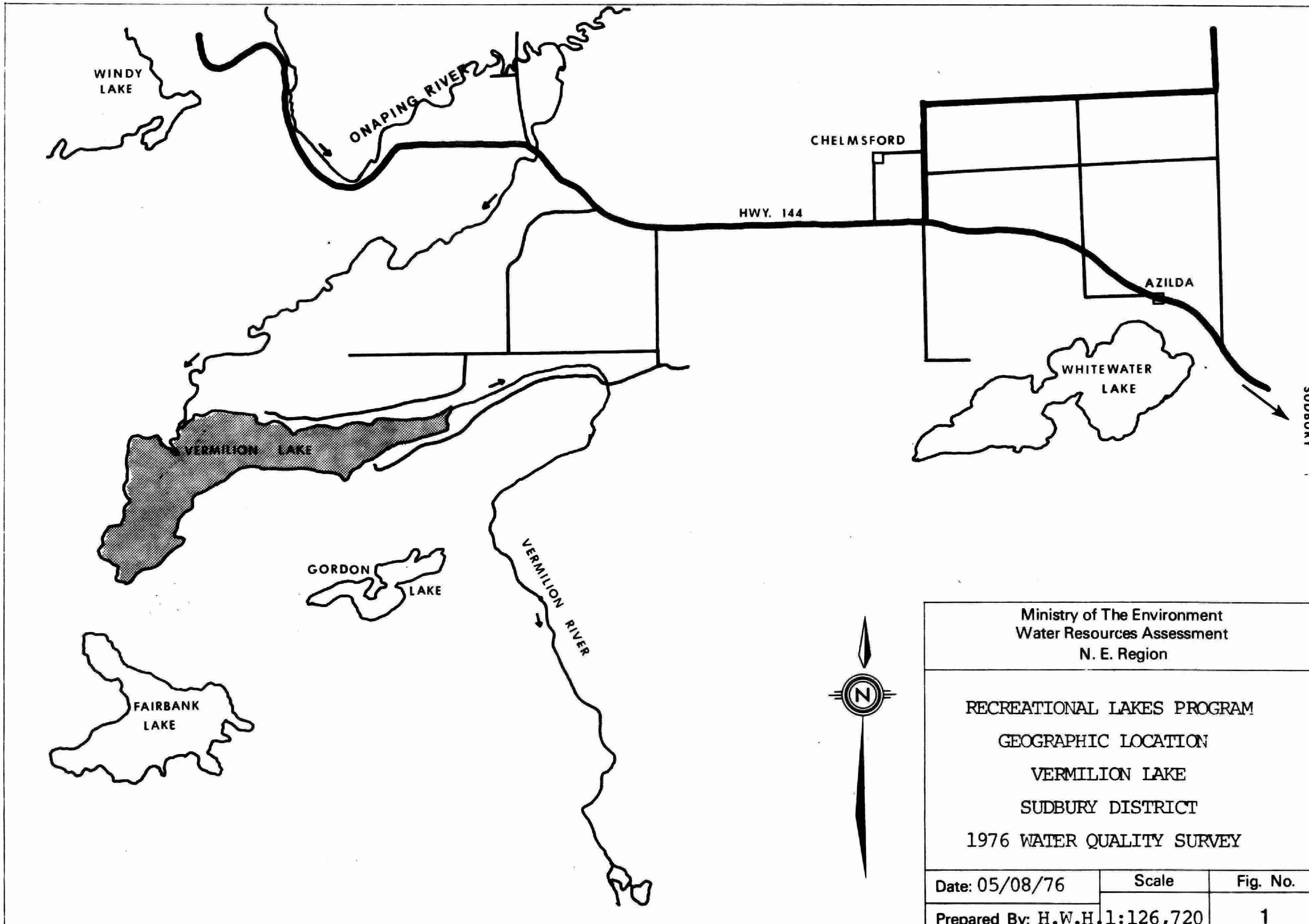
The purpose of the survey was to define the chemical and bacteriological water quality of Vermilion Lake as it pertains to the recreational pressure to which the lake is subjected.

Data obtained during the study were used to calculate a phosphorus budget for the lake. The potential effect of further housing development on this budget and the projected impact on existing water quality were examined.

STUDY AREA DESCRIPTION

Vermilion Lake is located south of Highway 144 in Fairbank Township, Sudbury District. The nearest large population centre, the City of Sudbury, is located approximately 33 kilometers east of the Lake (Figure 1).

Although Vermilion Lake is found in the Precambrian Shield which is characterized by granitic bedrock with thin overburden, it is situated within the central part of the Sudbury Basin which contains metasediments and metavolcanics.



Ministry of The Environment
Water Resources Assessment
N. E. Region

RECREATIONAL LAKES PROGRAM
GEOGRAPHIC LOCATION
VERMILION LAKE
SUDBURY DISTRICT
1976 WATER QUALITY SURVEY

Date: 05/08/76	Scale	Fig. No.
Prepared By: H.W.H.	1:126,720	1

Vermilion Lake's physical characteristics are listed below:

Surface area	10.79 km^2
Maximum depth	13.1 m
Mean depth	4.69 m
Volume	50.58 x 10^6 m^3
Flushing rate	21.42/yr.

The drainage basin, whose topography is mainly characterized by rugged Precambrian terrain, covers an area of approximately 2850 km^2 (1100 sq. miles). Of this, 778 km^2 are within the Onaping River watershed below the influence of the Bannerman Creek diversion while 2072 km^2 are within the Vermilion River watershed.

The level and outflow volume of Vermilion Lake are controlled by the Stobie dam which is located at the east end outlet. It is operated by E.B. Eddy Forest Products Limited in Espanola.

Based on Ministry of Natural Resources 1970 survey data, there are approximately 144 seasonal and year-round dwellings on the shoreline.

Recreational activities enjoyed by area residents include summer and winter fishing, boating, swimming, snowmobiling and duck hunting.

The main non-water quality problem identified by local residents is the uncertainty of the water level which can be varied as much as 2m (6 feet) by the control dam. However, because the Stobie dam performs a function in flood control, water storage and the regulation of downstream flows, the maintenance of a water level strictly suitable to the requirement of Vermilion Lake cottagers is difficult.

SURVEY PROCEDURES

A) Chemical Water Quality.

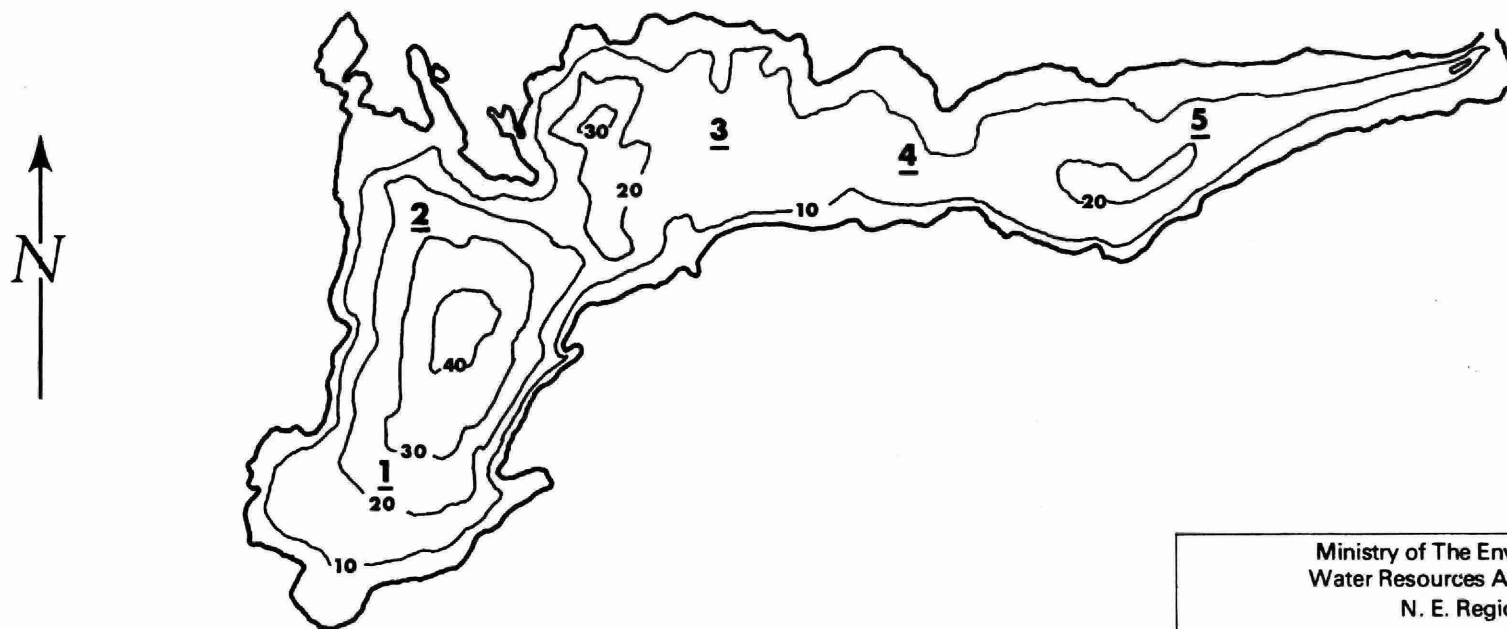
Five stations on the lake were sampled on four separate occasions from May 26 to August 18, 1976. Sampling stations and lake bottom contours are shown in Figure 2.

During May and June, composite samples of the euphotic zone (depth of light penetration adequate to support plant growth) were taken for water chemistry analysis. In July and August, water samples for chemical analysis were obtained one metre below the surface and one metre off the bottom with a Van Dorn bottle.

Chemical analyses performed on water samples included:

hardness	total phosphorus
alkalinity	total Kjeldahl nitrogen
pH	ammonia
conductivity	nitrite
colour	nitrate
calcium	inorganic carbon
magnesium	iron
	chloride
	sulphate

Water transparency was measured on eight separate occasions spanning the June to September period by lowering a Secchi disc (20 cm diameter metallic disc painted in alternate black and white quadrants) until it disappeared from view. At the same time, water samples for chlorophyll a determination (the green pigment in algae) were secured as euphotic zone composites.



1-Chemical Sampling Locations

Ministry of The Environment
Water Resources Assessment
N. E. Region

Bottom Contours (feet)
of
Vermilion Lake
Fairbank Twp.

Date: 24/05/77	Scale	Fig. No.
Prepared By: H. W. H.	1:50,000	2

Dissolved oxygen and temperature profiles useful in the interpretation of water quality, were developed at each sampling location during the July and August chemical surveys by means of a Y.S.I. Model 54 combination meter.

Chemical analyses other than pH, which was determined subsequent to sample collection, were carried out at the Ministry of the Environment Laboratory in Toronto.

Chemical Tests and Interpretation.

The determination of chemical water quality involves evaluation of the concentrations and distribution of particular chemical species. Characterization parameters which are used to "describe" a water include:

Hardness, the soap consuming ability of a water.

Calcium and Magnesium, the major cations contributing to hardness.

Conductivity, a measure of the ability of water to pass an electric current. It is used as an indication of quantities of dissolved substances.

pH, a measure of acidic or basic properties of water. A reading above 7 is basic while values less than 7 are acidic.

Colour, a determination of the intensity of the yellow-orange hue contributed to lakes by organic material or iron.

Alkalinity, a measure of a water's ability to resist pH change from acidic inputs.

Nutrient parameters including; total phosphorus, the four interrelated forms of nitrogen, and inorganic carbon are used to determine the enrichment or trophic status of a lake. Nutrient poor or oligotrophic lakes are usually very clean and clear while eutrophic or nutrient rich lakes are characterized by turbid water caused by extensive growths of algae and aquatic weeds.

Other chemical species examined are iron, which can impart colour, odour and taste to natural water, and chloride and sulphate which can be indicative of pollution inputs resulting from the activities of man.

Indications of lake trophic status and water quality are also obtained from the investigation of biological and physical conditions.

Primary biological activity is evaluated by measuring the concentration of chlorophyll *a* the green pigment in algae (tiny plants suspended in the water column). At the same time, water clarity or transparency is determined by lowering a black and white Secchi disc until it disappears from view.

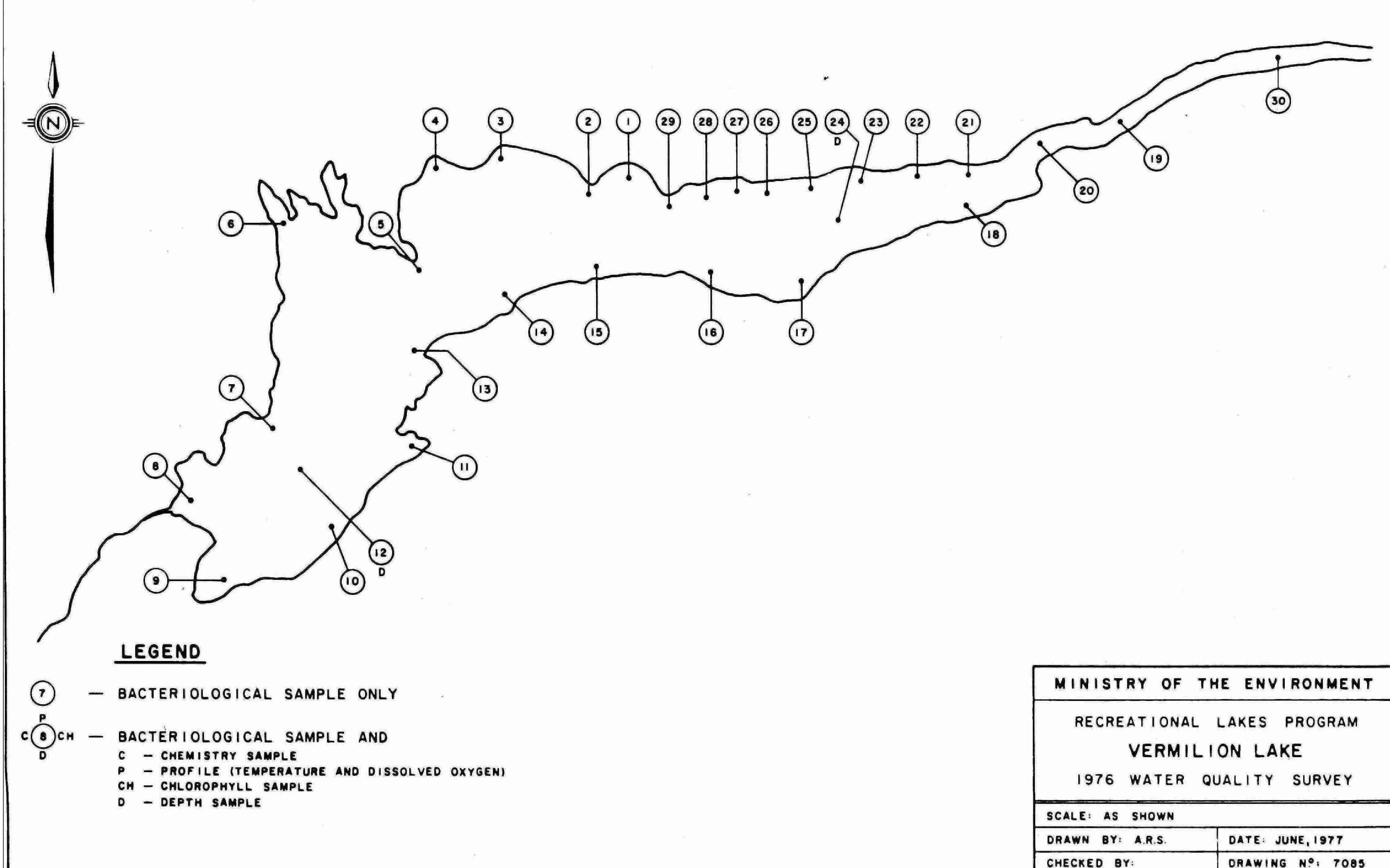
The mid to late summer vertical distributions of dissolved oxygen and water temperature can be used to explain many of the conditions encountered and to estimate the potential for the occurrence of specific water quality problems like algae blooms, odours and fish mortalities.

B) Bacteriological Water Quality

Bacteriological surveys were carried out over two consecutive five day periods lasting from June 5 to June 9 and July 24 to July 28, 1976.

Sampling stations were located at the outflow, the inflows, in the open lake and in 28 near shore locations considered to be representative of the various degrees of shoreline development found on the lake (Figure 3).

FIGURE 3 - LOCATION OF BACTERIOLOGICAL SAMPLING STATIONS ON VERMILION LAKE



Samples were obtained one metre below the surface at each station as well as one metre above the bottom at the midlake stations.

Bacteriological Methods

Four kinds of bacteria, total coliform, fecal coliform, fecal streptococcus bacteria, and *Pseudomonas aeruginosa* are all indigenous to man and other warm-blooded animals, and are found in the colon and feces in tremendous numbers. Many diseases common to man can be transmitted by feces; consequently, the probability of occurrence of such diseases is highest in areas where the water is contaminated with fecal material. These indicator organisms in water connote the possible presence of disease causing organisms.

The density of the indicator bacteria in water will vary considerably between samples taken at the same station, or at different stations on a lake, or if taken at different times, and so the assessment of water quality cannot be determined accurately from a single water sample. Therefore, the bacteriological surveys require many samples to be taken at several lake stations over a period of time. The large amount of data obtained is reduced by calculations to meaningful and easily manipulated statistics.

The data for Vermilion Lake were evaluated by statistical techniques in the following manner. The geometric mean, the most appropriate central value, and variance were calculated

for the values of each of the four kinds of bacteria at every station, providing concise valid data. Statistically significant variation in the bacterial densities between stations, or groups of stations, was determined by a One-Way Analysis of Variance and Bartlett's Test of Homogeneity. By these means, the data from each station were tested against that of every other station until all stations with similar geometric mean densities were separated into groups (Group A, B).

The group results and those for individual stations were identified by different stippling on a summary map. Within each stippled area, the group geometric mean was applicable for each type of bacteria unless otherwise indicated by individual station values. The areas of better or worse bacterial densities were defined by the group geometric mean densities, and so, any inputs of bacterial contamination, and the area they affected, were identified.

RESULTS

The results of chemical analyses for water samples collected in May, June, July and August are shown in Tables 1 through 4. Tables 1 and 2 summarize water chemistry in the euphotic zone during the early summer, while Tables 3 and 4 compare surface and near-bottom water chemistry during mid and late summer.

SURFACE WATER CHEMISTRY CHARACTERISTICS

Monitoring of the Vermilion Lake surface water chemistry from May through August revealed that chemical water quality was variable with concentrations of many of the parameters increasing during the summer.

TABLE 1

CHEMICAL WATER QUALITY OF VERMILION LAKE

May 26, 1976

PARAMETER	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
Hardness	29	31	31	35	33
Alkalinity	14	12	16	13	15
pH	7.45	7.25	7.42	7.37	7.18
Conductivity	80	80	85	85	85
Colour	15	20	30	30	30
Total Phosphorus	.013	.011	.013	.013	.014
Total Kjeldahl Nitrogen	.29	.24	.24	.23	.30
Nitrite	.003	.002	.003	.003	.003
Nitrate	.027	.033	.047	.032	.032
Inorganic Carbon	1.7	1.7	2.0	1.9	1.9

* All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen units).

TABLE 2

CHEMICAL WATER QUALITY OF VERMILION LAKE

June 9, 1976

PARAMETER	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
Hardness	33	33	36	36	30
Alkalinity	14	14	14	15	14
pH	7.10	6.95	7.02	7.11	7.02
Conductivity	88	85	96	97	93
Colour	15	15	15	15	10
Total Phosphorus	.015	.015	.013	.015	.014
Total Kjeldahl Nitrogen	.28	.28	.28	.30	.28
Ammonia	.012	.008	.010	.008	.002
Nitrite	.002	.002	.002	.002	.002
Nitrate	.008	.008	.012	.008	.008
Iron	.19	.19	.24	.21	.22
Calcium	11	12	13	13	13
Magnesium	2.15	2.25	2.50	2.50	2.75
Chloride	2.5	2.5	3.0	2.5	2.5
Sulphate	12	13	13	14	16

* All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen units).

TABLE 3

SURFACE (S) AND NEAR-BOTTOM (B) WATER CHEMISTRY

VERMILION LAKE

July 27, 1976

PARAMETER	SURFACE BOTTOM	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
Hardness	S	45	44	48	43	45
	B	33	33	49	45	45
Alkalinity	S	19	20	22	21	21
	B	20	20	22	22	21
pH	S	7.23	7.25	7.40	7.32	7.10
	B	6.48	6.57	7.36	7.30	7.15
Conductivity	S	114	112	120	118	118
	B	94	93	120	120	118
Colour	S	15	10	15	10	10
	B	40	40	15	20	10
Total Phosphorus	S	.028	.009	.012	.016	.012
	B	.036	.019	.016	.046	.014
Total Kjeldahl Nitrogen	S	.23	.19	.21	.24	.24
	B	.46	.48	.30	.42	.23
Ammonia	S	.004	.004	.002	.002	.006
	B	.208	.198	.016	.012	.006
Nitrite	S	.001	.001	.001	.001	.001
	B	.002	.010	.001	.001	.001
Nitrate	S	<.005	<.005	<.005	<.005	<.005
	B	.013	.025	<.005	<.005	<.005
Iron	S	.10	.19	.21	.24	.24
	B	.88	.48	.30	.42	.23

* All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen units).

TABLE 4

SURFACE (S) AND NEAR-BOTTOM (B) WATER CHEMISTRY

VERMILION LAKE

August 18, 1976

PARAMETER	SURFACE BOTTOM	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
Hardness	S	48	48	53	49	47
	B	42	40	53	51	47
Alkalinity	S	20	20	22	11	21
	B	26	27	22	22	22
pH	S	7.15	7.25	7.30	7.21	7.40
	B	6.50	6.45	7.15	7.06	7.35
Conductivity	S	128	128	144	132	128
	B	115	115	146	138	128
Colour	S	15	15	15	5	5
	B	70	70	10	10	15
Total Phosphorus	S	.026	.020	.017	.011	.017
	B	.075	.040	.020	.016	.017
Total Kjeldahl Nitrogen	S	.28	.24	.24	.24	.27
	B	.70	.85	.30	.18	.23
Ammonia	S	.014	.012	.010	.002	.006
	B	.312	.310	.008	.006	.004
Nitrite	S	.001	.001	.001	.001	.001
	B	.005	.004	.001	.001	.001
Nitrate	S	.024	.014	.014	.005	.006
	B	.015	.006	.006	.005	.004
Iron	S	.09	.07	.10	.08	.11
	B	3.0	2.3	.35	.21	.06
Calcium	S	14.2	14.4	16.2	15.4	14
	B	11.8	11.8	16.2	15.4	14
Magnesium	S	3.0	3.0	3.0	2.5	3.0
	B	3.0	2.5	3.0	3.0	3.0
Chloride	S	5.7	5.6	5.5	5.5	5.5
	B	3.2	3.4	5.5	5.5	5.5
Sulphate	S	22	20	21	21	21
	B	18	18	20	21	21

* All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen units).

Surface water chemistry data characterized Vermilion Lake as a softwater (hardness 29-53 mg/L), lightly yellow (colour 15 Hazen units), slightly basic (pH 7.2) lake with a moderate load of dissolved elements (conductivity 80-146 umhos/cm) and fair buffering capacity (alkalinity 11-22 mg/L). Concentrations of the major nutrient elements, phosphorus (.011-.028 mg/L) and nitrogen (.300 mg/L) were moderate while inorganic carbon concentrations were low (1.8 mg/L).

Concentrations of iron in the surface waters ranged from .07 to .24 mg/L and were below the drinking water criterion of .30 mg/L. The major cations, calcium (11-16 mg/L) and magnesium (2.5-3 mg/L) were present in moderate quantities as were chloride (2.5-5.7 mg/L) and sulphate (12-22 mg/L), the main anions.

TEMPERATURE AND DISSOLVED OXYGEN

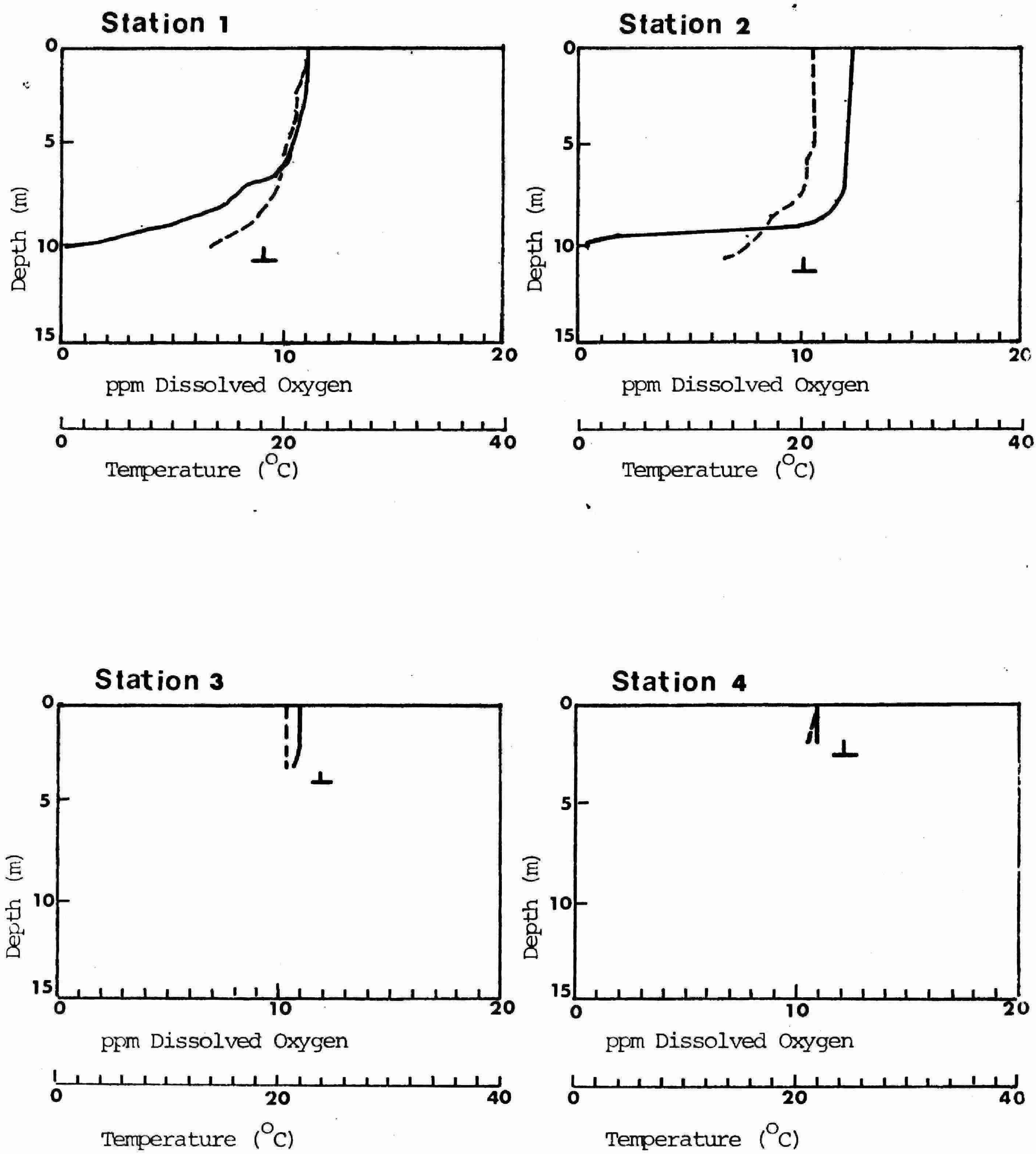
Mid to late summer is the critical period for the determination of dissolved oxygen distribution in lake basins that become thermally stratified.

Dissolved oxygen and temperature profiles are shown in Figures 4 and 5. Because station 5 was shallow and exhibited information similar to stations 3 and 4, it was excluded from the figures.

Oxygen and temperature profiles developed in mid July (Figure 4) revealed weak thermal stratification with declining water temperatures near the bottom of deep stations 1 and 2. Elsewhere homothermal (equal temperature) conditions prevailed. By mid August, water temperatures were almost uniform from surface to bottom throughout the lake except near the bottom of stations 1 and 2 where slightly cooler water was found (Figure 5).

Dissolved Oxygen - Temperature Profiles

Summer 1976 Vermilion Lake July



——— Dissolved Oxygen Curve

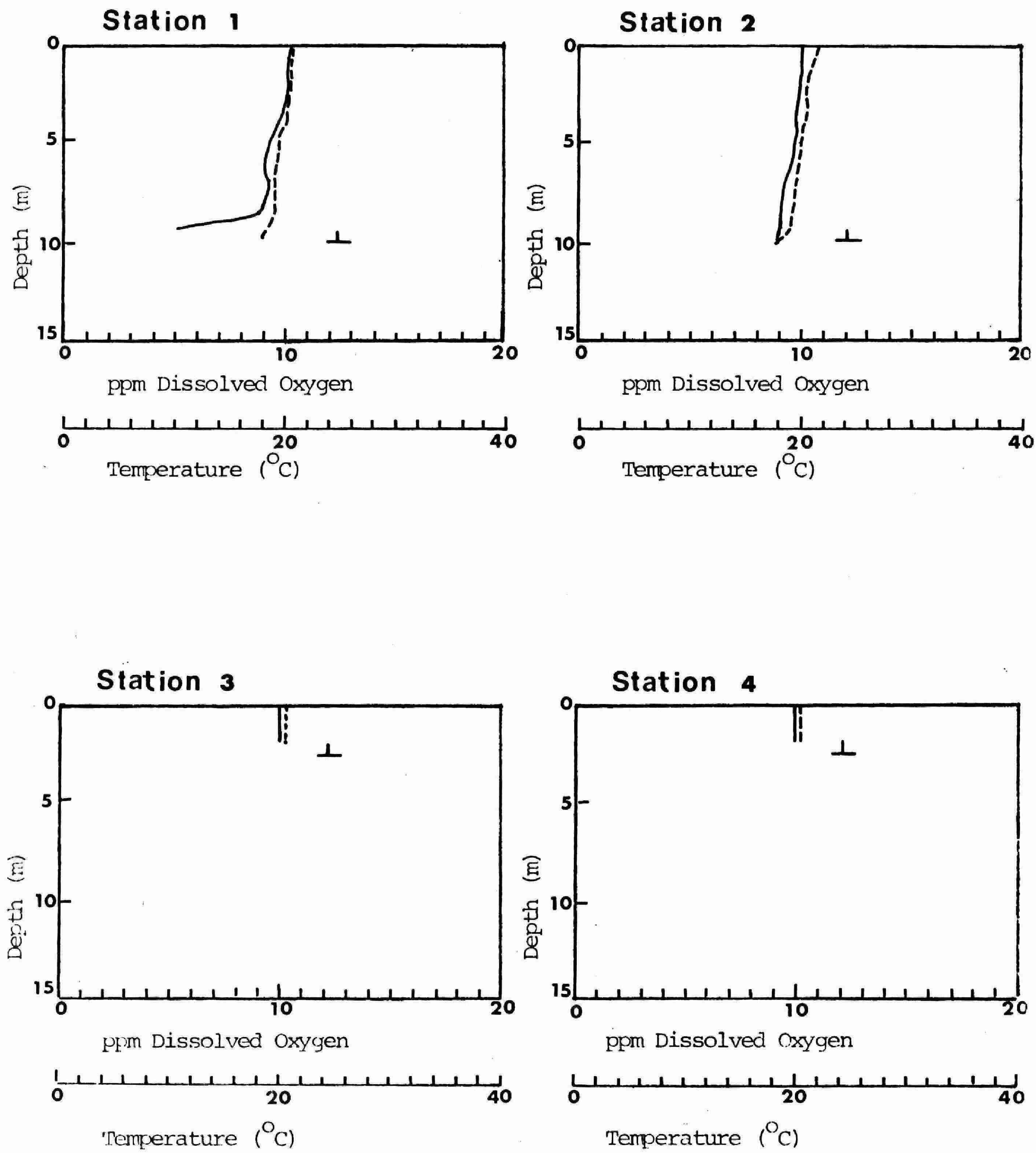
- - - - - - Temperature Curve

⊥ Lake Bottom

FIG 4

Dissolved Oxygen - Temperature Profiles

Vermilion Lake August 1976



——— Dissolved Oxygen Curve

- - - - - - Temperature Curve

⊥ Lake Bottom

FIG 5

In July, dissolved oxygen concentrations at stations 1 and 2 at the west end of Vermilion Lake were approximately 11 mg/L in the surface 7m and declined to less than 1 mg/L near the bottom where weak thermal stratification was in effect. Because of wave and wind mixing, the shallow sampling stations exhibited uniform dissolved oxygen concentrations of 11 mg/L.

By August when thermal layering was not apparent, fairly uniform vertical oxygen distribution was observed at each location (approximately 9.5 mg/L), although lower concentrations (5 mg/L) were detected one metre from the bottom of stations 1 and 2.

From the partial thermal record available in the survey data, it appears that thermal stratification of the deeper western basin of Vermilion Lake is present during the early to mid summer period, or, for as long a time as is required for the water column to become uniformly heated.

The pronounced drop of dissolved oxygen concentrations in the cooler, near-bottom zone of stations 1 and 2 observed in mid July, was the result of bacterial oxidation of sedimented organic material coupled with sediment oxygen demand.

It appeared that the oxygen demand of the highly organic sediment in the western basin was sufficient to maintain depressed oxygen concentrations near the bottom under near homothermal conditions in mid August. However, it was also possible that during the sampling period the thermal barrier between the warm surface and cool bottom waters was in a late stage of decay. The lower oxygen concentrations found

near the bottom in August may have been the result of slow diffusion of oxygen from the more highly oxygenated surface water. Water chemistry data tend to support the latter explanation.

WATER CHEMISTRY EVALUATION

As previously stated, Vermilion Lake water chemistry was variable with concentrations of many of the parameters increasing during the summer. In particular, the characterization parameters, hardness, alkalinity and conductivity showed progressively increasing values during the sampling period. Average surface water concentrations are shown below:

	MAY	JUNE	JULY	AUGUST
Hardness mg/L	32	34	45	49
Alkalinity mg/L	14	14	21	21
Conductivity umhos/cm	83	92	116	132

At stations 1 and 2, chemical conditions 1m off the bottom were substantially different from those at the surface. Hardness and conductivity were significantly lower near the bottom (Tables 3 and 4).

Much of this water chemistry variation can be accounted for by the position of Vermilion Lake in the large Vermilion River watershed. Because Vermilion Lake is flushed relatively quickly, it is possible to consider it as a widening of the river whose water chemistry is largely determined by runoff and precipitation events in the watershed.

The parameter conductivity is used as an indication of quantities of dissolved substances.

In the spring, when the river flow was composed primarily of dilute thaw runoff, the conductivities measured were relatively low. By late summer, increased dissolved solids loading from terrestrial drainage and upstream human activity resulted in higher conductivity readings.

Thermal stratification, or water column partitioning due to density differences could account for the lower conductivities observed near the bottom of stations 1 and 2. The water in the bottom of the lake basin was likely residual from the more dilute spring flow.

The spring melt phenomenon is also a probable explanation for the seasonally increasing concentrations of the major cations (calcium, magnesium) and anions (chloride and sulphate).

Comparison of the lake survey information with the monthly records of water chemistry sampling of the Vermilion River at the Highway 144 bridge at Chelmsford (Water Quality Monitoring Program), approximately 13 km upstream of the lake, revealed similar seasonal increases in dissolved substances.

The pH readings at stations 1 and 2 taken 1 metre from the bottom were consistently more acidic than at the surface. The pH reduction (7.2 surface to 6.5 bottom) indicated the existence of reducing conditions in the sediments. Weak thermal stratification inhibiting complete mixing of the water column helped maintain the pH difference.

Overall, pH readings were near neutral and within the favourable range for the support of fish populations.

Iron concentrations in the euphotic zone (twice Secchi disc visibility) ranged from .07 to .24 mg/L, well below the Ministry of the Environment drinking water criterion of .30 mg/L. Near the bottom of sampling stations 1 and 2, a buildup of iron to an August maximum of 3 mg/L was measured. This increase was the result of reducing (low oxygen) conditions at the bottom of the lake basin and was largely responsible for the higher colour (40 units in July and higher than 70 in August) of the near-bottom water samples.

NUTRIENT CHARACTERISTICS

Total phosphorus concentrations in the surface waters ranged from .009 mg/L to .028 mg/L in individual samples, but the lake average was approximately .015 mg/L. This is considered to be a moderate average with the potential to support a moderate level of primary biological activity. The existence of a weak thermocline in the deep basin, reducing conditions near the bottom, and the activity of decomposer micro-organisms on sedimented organic matter, resulted in an increase of phosphorus in the bottom waters. High concentrations of .075 and .040 mg/L were measured at stations 1 and 2.

Following the breakdown of the thermal layers and mixing of the phosphorus rich bottom waters with the surface, a pulse of biological activity could be expected. However, because the volume of water containing high concentrations of phosphorus was relatively small, the impact on the overall water quality of the lake was expected to be minor.

In the normal course of decomposition of nitrogenous organic matter, nitrogen goes through the following form changes: Total Kjeldahl nitrogen to ammonia which is oxidized through the unstable nitrite form to nitrate.

Surface water concentrations of total Kjeldahl nitrogen were moderately low ranging from .19 to .30 mg/L and averaging .25 mg/L. Inorganic nitrogen concentrations; ammonia, nitrite and nitrate, were low and appeared to decline over the summer.

Bottom water quantities of nitrogen in the deep basin increased during the summer. In particular, total Kjeldahl nitrogen and ammonia were found in high concentrations (.80 and .312 mg/L). Since ammonia is included in the determination of total Kjeldahl nitrogen, it was not surprising to observe the joint increase in quantity; however, during the August 18 sampling the amount of Kjeldahl nitrogen present in the bottom waters was in excess of that which could be accounted for by the ammonia. This increase in Kjeldahl nitrogen and ammonia was the result of sedimentation and decomposition of organic matter in a zone of low oxidizing potential.

Like the phosphorus, the release of inorganic nitrogen to the surface waters during lake mixing could have induced increased algal activity. But, because the volume of water containing high concentrations of nitrogen was relatively small, no major impact was expected.

CHLOROPHYLL a - Secchi Disc

Densities of suspended algae, as measured by chlorophyll a concentrations varied throughout the summer.

Results of chlorophyll analysis and Secchi disc visibility are listed in Table 5 and summarized in Figure 6. As shown, chlorophyll a concentrations on a lake-wide basis varied within the 0-2 ug/L low and the 2-5 ug/L moderate range. The average for all five sampling stations, 2.6 ug/L was indicative of a moderate level of primary biological productivity.

Secchi disc visibility was generally at the low end of the 2.5 to 5 metre moderate range. Visibility was better at the deeper west end of the lake with average Secchi disc depths of 3.3 m at stations 1 and 2. The shallow eastern section of the lake, which was usually affected by wind and wave suspension of silt particles, had a lower average Secchi disc visibility of 2.5 m.

TABLE 5

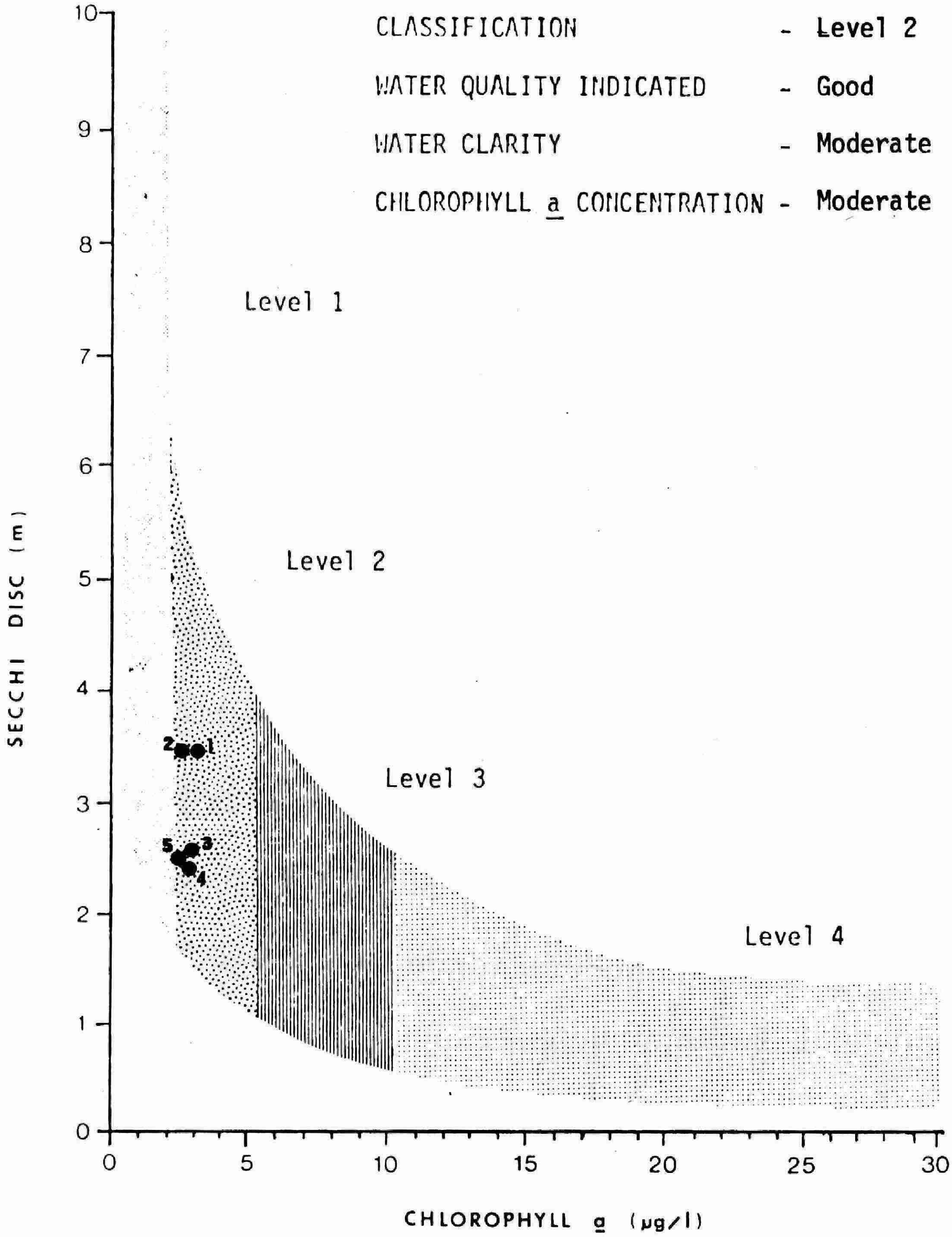
CHLOROPHYLL (CHL.) - SECCHI DISC (S.D.) DETERMINATIONS - VERMILION LAKE 1976

DATE	STATION 1		STATION 2		STATION 3		STATION 4		STATION 5	
	CHL.	S.D.	CHL.	S.D.	CHL.	S.D.	CHL.	S.D.	CHL.	S.D.
June 6	2.9	2.75	3.3	3.0	1.3	2.25	2.4	2.0	2.4	2.0
June 8	2.3	2.75	3.0	2.75	1.8	2.5	2.4	2.0	2.3	2.0
June 21	1.5	3.75	1.1	4.0	3.9	2.5	0.9	2.5	1.9	2.75
June 30	3.1	3.0	3.4	3.0	4.2	2.0	4.1	2.0	3.9	2.5
July 18	1.2	3.25	1.7	3.75	1.6	3.25	1.8	2.5	1.8	2.75
July 29	4.3	2.75	4.4	2.75	4.0	2.25	3.4	2.75	3.7	2.75
Aug. 30	2.5	4.75	2.7	3.75	2.2	3.5	2.3	3.0	2.1	3.0
MEAN	2.6	3.3	2.8	3.3	2.7	2.6	2.5	2.4	2.6	2.5

* Chlorophyll concentrations in ug/L
Secchi Disc visibility in metres.

VERMILION LAKE - FAIRBANKS TWP

1976



LAKE CLASSIFICATION BASED ON CHLOROPHYLL a SECCHI DISC RELATIONSHIP

KEY: Secchi Disc Visibility(m)

- 5 + excellent
- 2.5 - 5 moderate
- 1 - 2.5 low
- 0 - 1 poor

Chlorophyll a Concentration(ug/l)

- 0 - 2 low
- 2 - 5 moderate
- 5 - 10 high
- 10 + excessive

FIG 6

BACTERIOLOGY

During the June and July surveys, the water quality of the main body of Vermilion Lake was well within the Ministry of the Environment recreational use criteria which state:

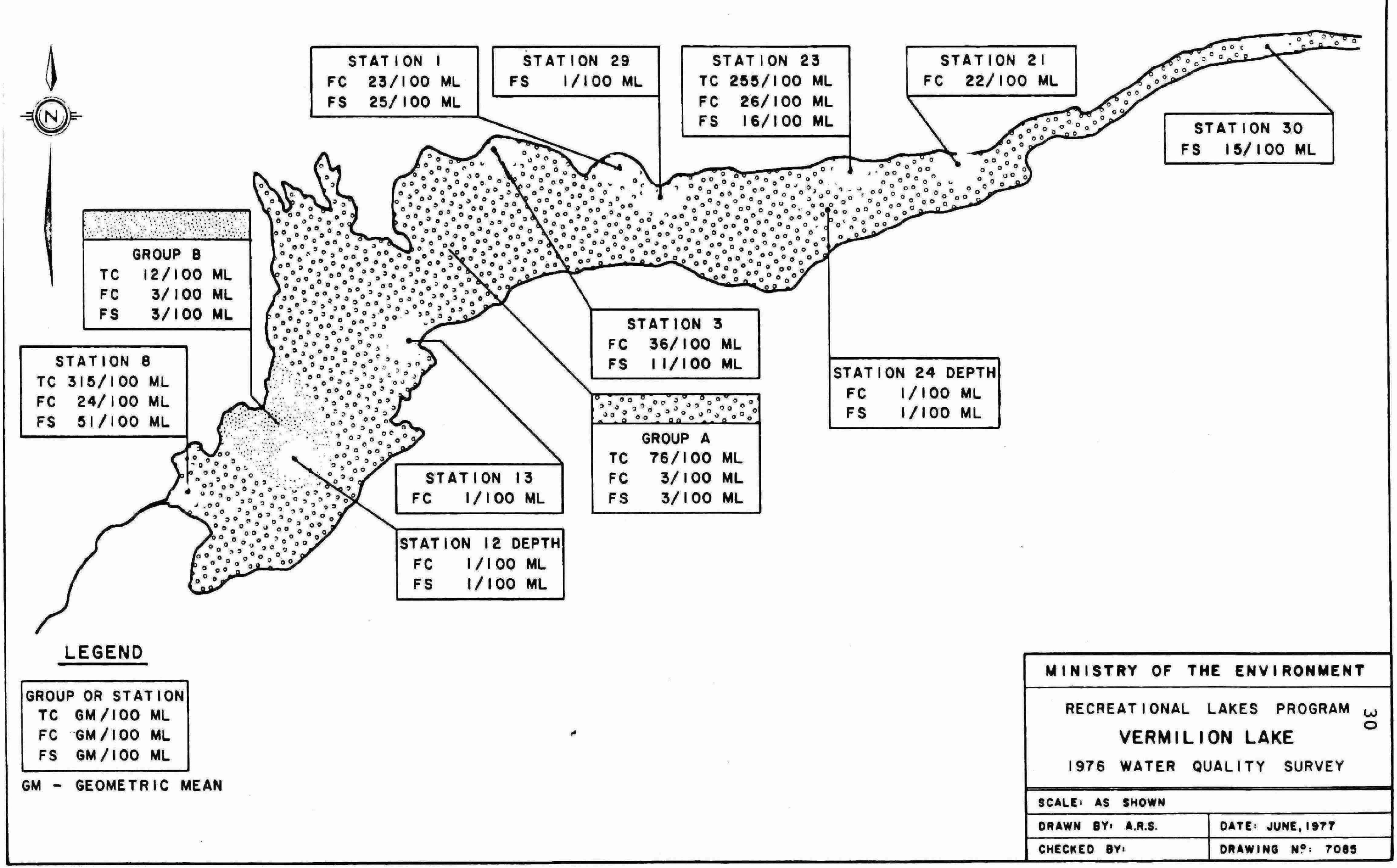
> "Where ingestion is probable, recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC) and/or enterococcus (fecal streptococcus, FS) geometric mean density exceeds 1000, 100 and/or 20 per 100 mL, respectively, in a series of at least ten samples per month including samples collected during weekend periods." *

In June, the geometric mean bacterial densities for the main part of the lake were 76 TC, 3 FC and 3 FS per 100 mL (Group A, Figure 7). A small area in the southwest part of the lake (Group B, Figure 7) had lower levels of total coliform (12 TC/100 mL) than was found in the main portion of the lake. Fecal coliform (FC) and fecal streptotoccus (FS) densities in this area, however, did not differ from those of Group A. At a rocky point (station 13) and in the bottom waters, stations 12D and 24D fecal coliform densities were 1 FC per 100 mL which was lower than those found in the main part of the lake.

Several isolated stations along the shoreline of the lake were found to have bacterial densities which exceeded those of the main body of lake water (Group A). Along the north shore a marina (station 1) and a beach and boat launching area (station 3) had levels of fecal bacteria of 23 FC and 25 FS/100 mL, and 36 FC and 11 FS/100 mL, respectively. At a beach area (station 29), the fecal streptococcus density was found to be only 1 FS/100 mL.

*Guidelines and Criteria for Water Quality Management in Ontario M.O.E. 1974.

FIGURE 7 - DISTRIBUTION OF BACTERIA FOR THE JUNE 5 TO JUNE 9 SURVEY

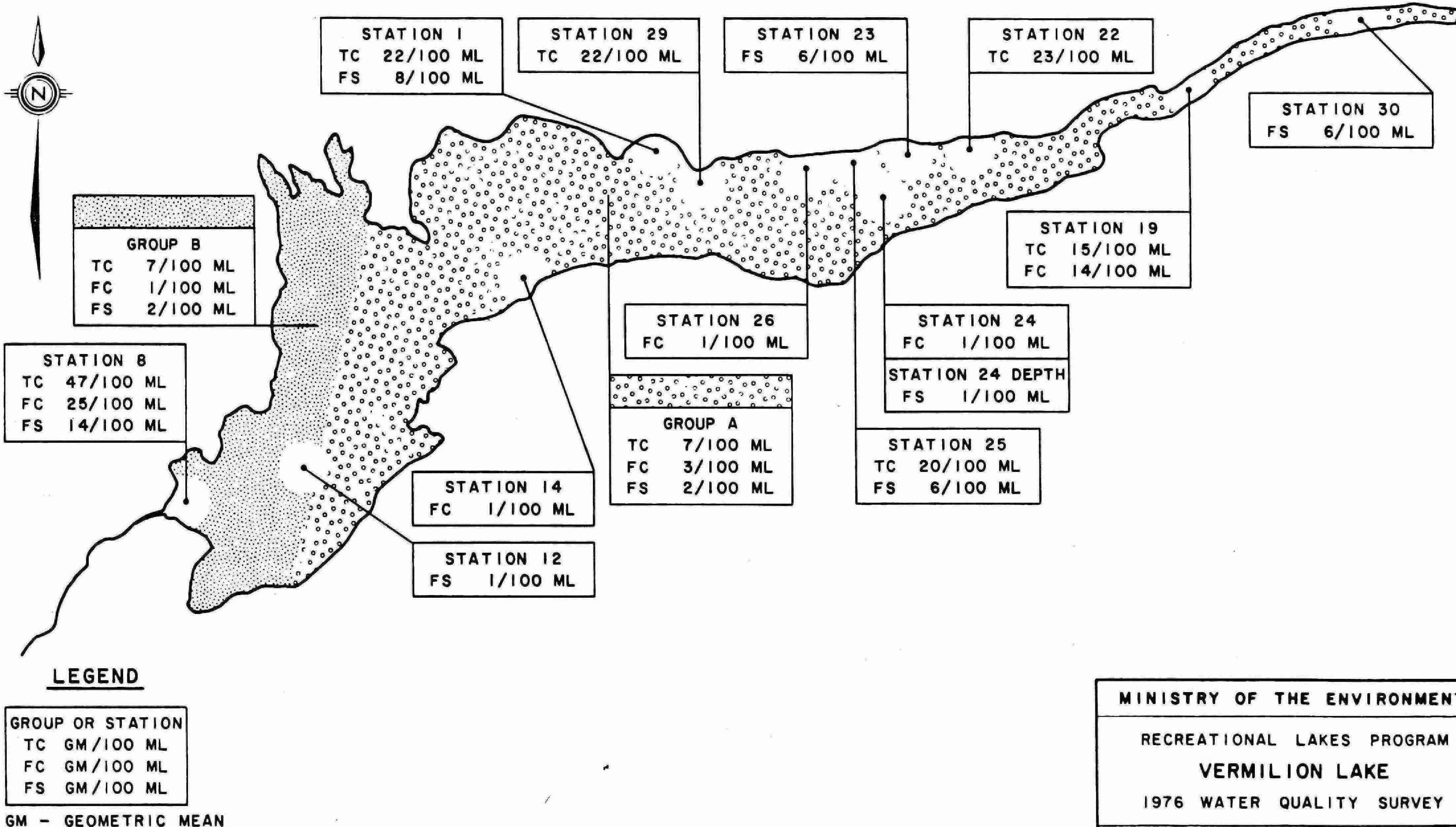


The elevated bacterial levels may have been due to increased human activities in these areas. A similar situation was also observed near a barn (station 21) at the northeast part of the lake, where the fecal coliform density was found to be 22 FC/100 mL. Further east, in the outflowing stream (station 30) at a bridge, a fecal streptococcus density of 15 FS/100 mL was observed. This did not represent a recent fecal source as the fecal coliform level was not correspondingly higher.

Localized water quality impairment was also indicated by the bacterial densities found near the mouths of two inflowing streams. Near the mouth of the southwestern stream (station 8), for example, the bacterial densities were found to be 315 TC, 24 FC, and 51 FS per 100 mL. Densities of bacteria at the mouth of the northeastern stream (station 23) were 255 TC, 26 FC, and 16 FS per 100 mL. Inflowing streams often have higher bacterial levels than the rest of the lake as they may transport various materials such as soil, decaying matter and possible animal and human wastes into the lake.

During the July survey the mean bacterial densities for the major portion of the lake were 7 TC, 3 FC, and 2 FS per 100 mL (Group A, Figure 8). A smaller area at the western end of Vermilion Lake (Group B) had bacterial densities of 7 TC, 1 FC, and 2 FS per 100 mL. Similar levels of fecal bacteria were found at the mid-lake sampling stations where low levels of bacteria were to be expected. The fecal coliform density of the surface water (station 24) was 1 FC/100 mL while the density of fecal streptococcus in the bottom water

FIGURE 8 - DISTRIBUTION OF BACTERIA FOR THE JULY 24 TO JULY 28 SURVEY



MINISTRY OF THE ENVIRONMENT

RECREATIONAL LAKES PROGRAM

VERMILION LAKE

1976 WATER QUALITY SURVEY

SCALE: AS SHOWN	
DRAWN BY: A.R.S.	DATE: JUNE, 1977
CHECKED BY:	DRAWING Nº: 7085

(station 24D) was found to be 1 FS/100 mL. The mid-lake waters at the western end of the lake (station 12) had a fecal streptococcus density of 1 FS/100 mL. Low levels of fecal coliform bacteria (1 FC/100 mL) were also found at stations 14 and 26.

In July, in agreement with the June survey a number of isolated stations on the north shore had bacterial levels higher than those of the main part of the lake. The marina (station 1) had densities of 22 TC and 8 FS per 100 mL while to the east, near a dock (station 25), the levels were 20 TC and 6FS per 100 mL. A trailer park (station 22) and a beach area (station 29) also had total coliform levels which exceeded those of the main part of the lake. Total coliform densities at the trailer park and beach area were 23 and 22 TC per 100 mL, respectively. None of these areas had high fecal coliform levels in July and consequently evidence of recent pollution was absent.

Stations in the exit channel at the eastern end of the lake (stations 19 and 30) and a station at the lake's western end (station 8) had higher bacterial levels than were found in the main portion of the lake. At a marshy area of the outflowing channel (station 19) the levels of bacteria were 15 TC and 14 FS per 100 mL while farther downstream at a bridge (station 30) the fecal streptococcus density was found to be 6 FS per 100 mL. At the mouth of the inflowing stream (station 8) densities of 47 TC, 25 FC, and 14 FS per 100 mL were observed. All of these locations had bacterial levels that were significantly higher than the rest of the lake, but none of the parameters exceeded the Ministry of the Environment recreational use criteria.

Bacterial levels in the main part of the lake did not change significantly from June to July. At several isolated stations along the north shore (stations 1, 3, 21, 23) fecal coliform densities decreased significantly from June to July indicating much lower pollution levels in the summer. Pseudomonas aeruginosa was not isolated in the June or July surveys which indicated that the mean density of this organism was very low.

Low levels of bacteria were found in most areas of the lake during both surveys. Exceptions were some stations along the north shore, where a possibility of human contamination existed, and at the inflow on the southwest shore. The water quality of Vermilion Lake was generally good and was suitable for recreational use during the summer.

VERMILION LAKE PHOSPHORUS BUDGET

In the Northeastern Region of the Ministry of the Environment a phosphorus budget approach is being used as an indication of water quality and as a prediction of water quality changes likely to occur following the development of shoreline housing units.

It has been found (Dillon,1974) that the trophic status (degree of nutrient enrichment) of lakes can be related to the amount of phosphorus present at lake spring turnover when the water is completely mixed.

General catagories or levels of water quality based on the quantity of total phosphorus present in the spring have been identified.

NOTE:

Concentrations of phosphorus are reported as mg/m^3. This is equivalent to ug/L.

Level 1 (Excellent)

Springtime phsophorus concentrations between 0 and 9.9 mg/m^3. Such lakes are primarily suited for body contact recreation because of extremely clear water and low order of biological productivity. In deep lakes, dissolved oxygen concentrations in hypolimnetic (bottom) waters will remain favourable for the support of cold water fish species like lake trout.

Level 2 (Good)

Springtime phosphorus concentrations between 10 and 18.5 mg/m^3. Lakes in this category are suitable for water-based recreation but the preservation of cold water fisheries is not guaranteed. Level 2 lakes are less clear with moderate primary biological activity.

Level 3 (Fair)

Springtime phosphorus concentrations between 18.5 and 29.9 mg/m^3. Level 3 lakes are characterized by reduced suitability for body contact aquatic recreation because of high concentrations of suspended algae and associated nuisances like odours and turbid water. Oxygen depletion in deep basins will be common and there is danger of winterkill of fish in shallow lakes.

Level 4 (Poor)

Springtime phosphorus concentrations above 30 mg/m^3. Such lakes are suitable only for warm water fisheries and there is considerable danger of winterkill of fish. Other recreational uses like swimming, boating and water skiing are extremely unpleasant.

The springtime phosphorus concentration of Vermilion Lake was determined for 8 stations in May 1976 (Figure 9). Total phosphorus ranged from 10 to 14 mg/m^3 and averaged 12.8 mg/m^3. Vermilion Lake was classified as a Level 2 lake with a "good" order of water quality.

Results and classification are in agreement with observations during the summertime water chemistry survey.

In the calculation of a phosphorus budget for Vermilion Lake two sources of phosphorus were considered:

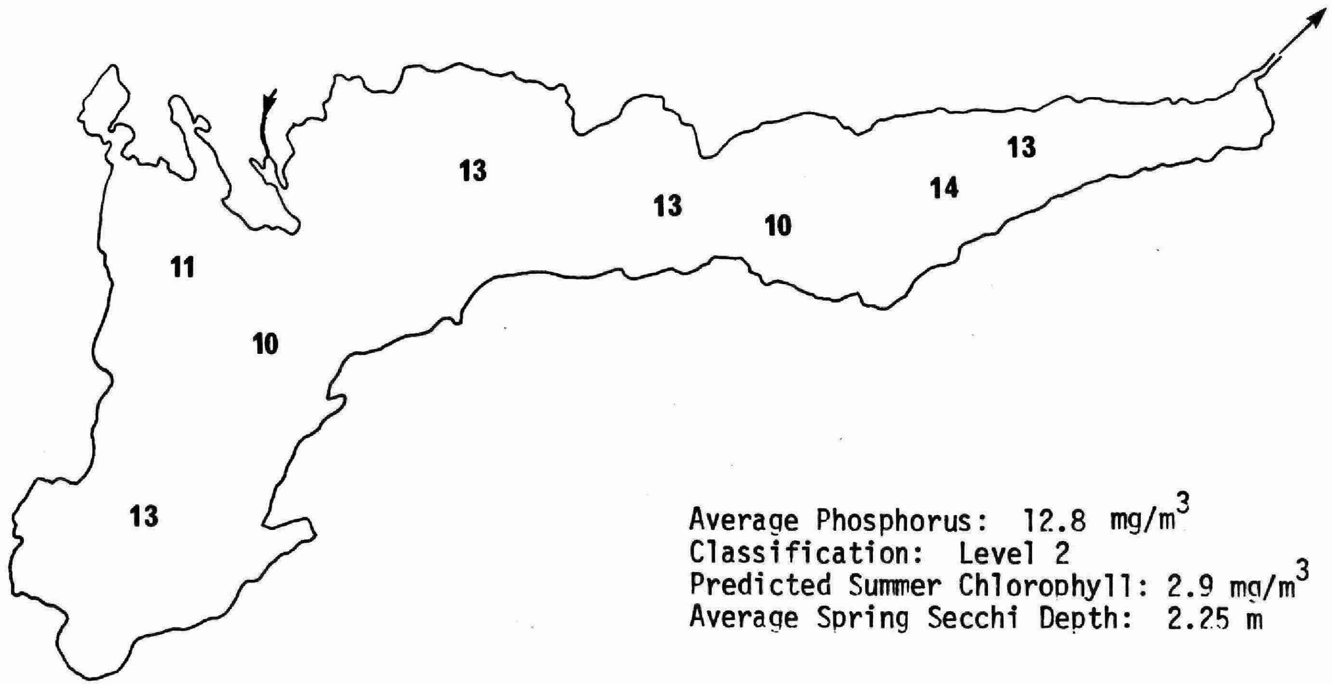
1. The phosphorus originating from the drainage basin i.e. natural load from runoff and precipitation. An export factor of 5.5 $mg/m^2/yr$ was used.

2. The artificial phosphorus input from septic tank tile fields of existing cottages and houses. Of the 144 dwellings on the lake it was assumed that 100 were seasonal.

SPRINGTIME PHOSPHORUS (mg/m^3)

1976

VERMILION LAKE   FAIRBANKS TWP



Average Phosphorus: 12.8 mg/m^3
Classification: Level 2
Predicted Summer Chlorophyll: 2.9 mg/m^3
Average Spring Secchi Depth: 2.25 m

FIG.9

For the estimation of septic tank phosphorus inputs, it was assumed that all phosphorus present in human waste finds its way to the lake. This amounts to approximately 800 gms/yr/person. For this reason, estimates of the effect of additional development are maximum effect estimates.

Phosphorus budget and development capacity were computed on an Hewlett Packard 9825A system. Results are shown in the appended outputs. Based on theoretical phosphorus supply estimates, a springtime phosphorus concentration of 13.6 mg/m^3 was predicted. It compares favourably with the measured value of 12.8 mg/m^3.

The more reliable, measured spring phosphorus value was used as a base for the calculation of development capacity. As shown in the outputs, Vermilion Lake has the ability to absorb numerous housing units. A total of 1989 cottages or 392 additional permanent dwellings will only have the potential to increase the spring phosphorus concentration 1 mg/m^3. Such an increase would result in a barely perceptible change in recreational water quality.

The large development capacity for Vermilion Lake is the result of it's rapid flushing rate. Water budget calculations show that the volume of Vermilion Lake is replaced 21 times per year on the average.

SUMMARY WATER QUALITY STATUS

The general chemical water quality of Vermilion Lake was good. Because the lake is relatively shallow it can be considered as a widening of the Vermilion River. For this

ONTARIO MINISTRY OF THE ENVIRONMENT - NORTHEAST REGION

LAKE DEVELOPMENT CAPACITY - DILLON'S MODEL

LAKE: VERMILION

TWP.: FAIRBANKS

DATE: MAR.1978

SUMMARY: This lake is classified as a Level 2 lake. This means that the Spring Phosphorus Concentration ranges from 9.9 to 18.5 mg/cu.m. A maximum of11342 cottages or2239 permanent dwellings may be added to maintain a Level 2 classification.

The addition of 1989 cottages or 392 permanent dwellings will result in a 1 mg/cu.m increase in the existing Spring Phosphorus Concentration.The full effect of any extra Phosphorus loading will be noticed after 0.1 years.

SUPPORTING DATA:

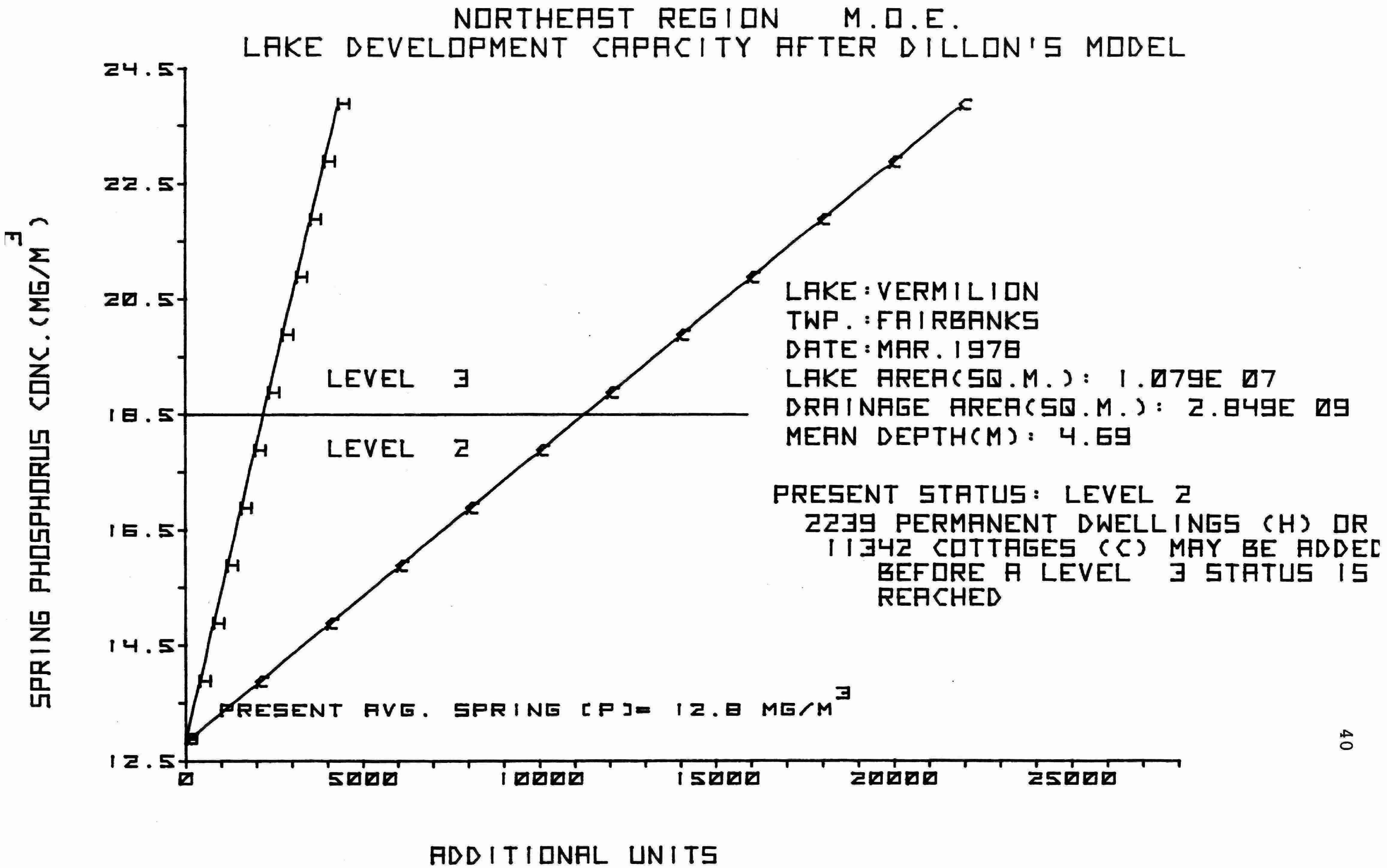
Lake Area(sq.m): 10785682
Drainage Area(sq.m): 2848986921
Mean Depth(m): 4.69
Volume(cu.m): 50584849
Unit Runoff(m/yr):0.3795
Precipitation(m/yr): 0.81
Evaporation(m/yr): 0.61
Total Outflow Volume(cu.m): 1083380030
Flushing Rate(Lake's vol./yr):21.4171
Retention Coefficient(R):0.1162
Response Time(yr): 0.1 to 0.1

Actual Phosphorus Loading(mg/sq.m/yr): 1454.67
Actual Phosphorus Supply(kg/yr): 15689.61

MEASURED SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 12.8

Theoretical Phosphorus Loading(mg/sq.m/yr): 1546.24
Theoretical Phosphorus Supply(kg/yr): 16677.23

THEORETICAL SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 13.6



NORTHEAST REGION M.O.E.
LAKE DEVELOPMENT CAPACITY AFTER DILLON'S MODEL
SPRING PHOSPHORUS CONC. (MG/M3)
24.5
22.5
20.5
18.5
16.5
14.5
12.5
LEVEL 3
LEVEL 2
LAKE: VERMILION
TWP.: FAIRBANKS
DATE: MAR. 1978
LAKE AREA(SQ.M.): 1.079E 07
DRAINAGE AREA(SQ.M.): 2.849E 09
MEAN DEPTH(M): 4.69
PRESENT STATUS: LEVEL 2
2239 PERMANENT DWELLINGS (H) OR
11342 COTTAGES (C) MAY BE ADDED
BEFORE A LEVEL 3 STATUS IS
REACHED
PRESENT AVG. SPRING [P]= 12.8 MG/M3
0
5000
10000
15000
20000
25000
ADDITIONAL UNITS

reason, the chemical water quality is in large part, controlled by river flow along with precipitation and runoff events in its large upstream watershed. If considered as a lake, Vermilion Lake would be classified as a mesotrophic, or moderately enriched body of water. Concentrations of nutrients, algae and other chemical constituents are within the moderate range.

Although, low oxygen concentrations, high iron and elevated nutrient levels were found at the bottom of the deeper western basin, they were considered to be natural events and did not pose a threat to the overall good level of water quality.

The bacteriological water quality of Vermilion Lake was also generally good. Some sources of fecal bacteria were identified along the populated north shore. They appeared to be associated with the marina, the boat launching ramp and some inflowing streams; however, none of the bacteriological parameters evaluated exceeded the Ministry of the Environment recreational use criteria.

A theoretical phosphorus budget and development capacity based on the ability of Vermilion Lake to assimilate additional nutrient loading, revealed that the actual phosphorus concentration present was consistent with expected levels. Because the flushing rate of the lake was high, a large development capacity was predicted.

BIBLIOGRAPHY

1. Dillon, P.J., 1974. A Manual For Calculating the Capacity of a Lake for Development. Ontario Ministry of the Environment.

2. Guidelines and Criteria for Water Quality Management in Ontario. Ministry of the Environment, 1974.